ECONOMY

IN THE

GENERATION OF STEAM,

WITH

SOME SUGGESTIONS

UPON THE PROPOSED

SUBSTITUTION OF COAL FOR WOOD UPON RAILROADS.

Armory, Jonathan + others

BOSTON:
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COMBUSTION OF FUEL.

In presenting to public attention the subject of economy in fuel, it is not proposed to attempt any scientific discussion of principles, but simply to offer some few results of practical experience. With these are also submitted the plans and drawings of the improved furnace, from which the results have been obtained. The experiments were fairly tried and attended with uniform success. The improved construction demands no additional outlay, and effects a saving in the generality of instances of fully one-half the amount of fuel usually required for the same work.

The ground covered by our new method is extensive, embracing the economizing of coals or wood, in all the different forms in which they are used. The principles involved are alike applicable to locomotive, marine and stationary boilers, to the puddling and common house furnace, and can be adapted with slight alterations to furnaces already in use as well as to new constructions.

It will be observed that the results of the various successful experiments of our system, during years of trial and under the most rigorous tests, set forth in the report of Mr. Eliot, Capt. Swift and Mr. Hale, hereto annexed, are taken from the certificates of persons well able to judge of its merits. Many of them are from scientific persons and others of the highest authority, from the superintendents of machine shops, manufacturing and railroad corporations.

A contract with the United States Government, conditioned upon the saving of a certain amount of fuel at the Navy Yard at Charlestown, has been acknowledged by the department at Washington to have been fulfilled. It was stipulated that by

means of our curves applied to their furnaces twenty-five per cent. of the quantity of fuel usually consumed should be saved. After a trial of three years, and saving with twelve boilers fifteen thousand dollars, we have received from the Government our compensation.

The most important uses, to which the improvements in steam of the Franklin Locomotive Company can be applied, are the present requirements of economy in the use of fuel on our railroads and in steamers. It is to this object that the public attention is more especially invited. But there can be no more important consideration in our usual avocations connected with steam, than to provide for the safety as well as comfort of the traveller, and at the same time to protect the engineer and fireman from the great risks to which they are exposed. By closing the front of the furnaces, introducing the air from the opposite end of the locomotive, or from the rear of a stationary boiler, the ash-pit may be kept closed, the fire-room or foot-board kept comparatively cool, and the water prevented, in case of accidents on ship-board, from putting out the fires.

Although our new modes of application are calculated to evolve the highest possible measure of heat from all the varieties of fuel, there are circumstances which entitle them to especial appreciation at this particular period. Wood has been growing more and more expensive. Our New England forests are becoming rapidly exhausted, to the great prejudice of future generations, and without benefit to our own. Coal on locomotives is shortly destined to take its place, and the greater capacity of coal for producing heat is quite as obvious in this application as in any other. A ton of coal is generally considered quite equal in heating power to two cords of wood, and one cord, cut and prepared for the tender, costs on the average as much as that quantity of coal. Coke, as used in England, would be too expensive for this country west of the Alleghany, as we have no suitable coal beds sufficiently accessible for economical use in this form. Locomotives on English roads will not furnish, therefore, models for our purposes, and new forms and arrangements must be contrived for the combustion of such coal as we can economically employ. In the introduction of changes, which must of course be gradual, energetic measures to stimulate invention, and thus secure the best models, would seem the part of wisdom.

It may be asked if coal is more economical than wood for railroad purposes, why it had not been already substituted. The reason generally assigned has been a fear of burning out

the fire-box, the increased heat in a contracted space being considered destructive to the tubes and metal surfaces. We consider this objection entirely obviated in our arrangement by slower combustion in a larger chamber and by the application of heated air, affording a higher evaporation with one-half the usual amount of fuel.

The prominent point to be gained in all attempted improvements in this direction, is to secure from the fuel in generating steam or other useful applications, all the heating power of which it is capable. It is well known that in theory the greatest possible evaporation of water by a given quantity of coal, is more than as much again as that usually realized in the common processes.

The annexed plans will serve to explain more clearly than any verbal description, the application of our principle to secure a nearer approval to perfection than has been as yet attained by the methods now in use.

In Plan A. is presented the commonly-used American wood-burning Engine.

In Plan B. an English Coke Locomotive, in which it is customary to use Coke and Coal together; but generally without any greater economy than that of the wood-burning Engine.

In Plan C. will be observed the construction of our proposed Locomotive furnace, with about two-thirds the usual number of tubes. It has a recess boiler with combustion chamber. For the greater prevention of smoke, to secure more perfect ignition, as also for other purposes hereafter to be more fully explained, the plan represents our improved mode of supplying the fire with air already heated. This latter improvement, applied to the boilers of the government at the Navy Yard, to those exhibited at the Crystal Palace in New York, and to Locomotives on several railroads, has been attended with marked success.

In Plan D. is represented a puddling furnace now under trial in Belgium.

Plan E. is a stationary boiler, of the same model as one used for experiments at Canton in this State, under the general supervision of the Scientific School at Cambridge. The report of Professors Horsford and Eustis is submitted.

Plan G. is a house furnace, with the adaptation of some of the leading features of our proposed system. A furnace upon this model, in operation during the past winter, has yielded an unusual amount of heat at comparatively little expense.

The application of our system to Locomotives has been already explained in connection with the Plan. The tubes

diminished in number and somewhat shortened, but not so as to diminish the effective surface exposed to the fire a recess boiler, the introduction of the curves for the retention and reverberation of the flame, and the admission of air from the anterior part of the Engine, by means of a feeder, which, passing through the combustion chamber, delivers it to the fire at a high temperature, are its principal characteristics.

By this combined arrangement, the combustion in most cases is without smoke, and should any chance to escape the bars, it is destroyed by the heated air of the combustion chamber, which consequently enters the tubes pure from lamp black. The fuel is thus converted into its most useful purity, and the points of heat passing up and down are presented to the surface of the water, producing the highest possible evaporation.

Slow combustion has long been the subject of discussion and careful experiment in Europe, and has been extensively introduced into practical use as affording the highest evaporation.

Mr. Wicksteed, whose valuable reports upon our system are worthy of attentive consideration, told us that he had brought slow combustion to such perfection, by care in firing, that the smoke would come into the stoke-hole through the door of the furnace. He has long been regarded as the highest authority by the Engineers of the Admirality, and others interested in the subject, and considered to have economized fuel beyond any other person in England. He gave this as a reason why we should not probably exceed him in economy. So assured was Mr. Lloyd, of the Admirality, of this, that he agreed to make Mr. Wicksteed's certificate of any gain we should accomplish over his results, the test of our superiority of arrangement without farther trial; saying that Mr. Wicksteed had beaten any thing which they had been able to do in England by fifteen per cent It will be seen by these tables and reports, herewith submitted, of our experiments in England, that credit is given us for thirty-seven and one-half per cent. over the average amount of saving.

With the ordinary mode of construction, however, in order to obtain any great measure of success from slow combustion, extreme watchfulness on the part of the fireman is absolutely essential, and the results in consequence have not as invariably afforded satisfaction, as the theory had led the parties interested to anticipate. In one establishment, visited not long since in England, the annual compensation of the principal fireman was twelve hundred dollars, a salary unusually large in comparison with the general rates in that country, and paid for the

express purpose of securing increased attention and judgment in this particular. He had the supervision of ten boilers, and the great saving of fuel, with the increased development of power, fully justified the wisdom of the expenditure. Much remains to be accomplished in this same direction among ourselves, and this will greatly be promoted by the adoption of our system. Less attention, and that more regular is required by it than by any other known to us, and the fireman might almost be guided day after day as to the proper times of firing by the clock, the damper being lower, the steam more regular, and the slow combustion more perfectly uniform.

A serious objection to the ordinary construction of the furnace is that the flame passes too rapidly. More time is needed for intermingling its gases, and it is only by its retention and reverberation, heated by currents of hot air, that all the valuable products of combustion are secured, and none permitted to escape by the chimney.

With the usual marine furnace, it is generally admitted, that to gain any high degree of speed, requires rapid combustion and a constant stirring of the fires; thus creating certainly more heat for the boilers, but much more for the stack. The necessary consumption of fuel increases in a much greater ratio than the speed. This is in some measure owing to the increased resistance of the water, but mainly to the waste of fuel from excessive agitation. This great addition to the expense, out of all proportion to the object accomplished, is very discouraging. We feel assured that by slow combustion upon our system, this serious obstacle in the way of rapidity of movement, both on the water and the land, can be in a great degree surmounted.

Too much importance cannot be attached to the superiority of our system over every other in preventing smoke. The smoke which escapes the chimney is for the most part carbonic oxide, and with it mingled fine solid particles of coal. This is pure loss. Could it be consumed, it would yield much additional heat. Besides being an extravagant waste of fuel, smoke is disagreeable, many ways injurious to articles of value, and highly prejudicial to health. To consume the smoke, it is necessary that it should be supplied freely with oxygen, and that there should be sufficient intensity of heat to ignite it when so supplied.

The great error in all the smoke-consuming furnaces heretofore produced, has been in bringing the fresh air cold to supply the requisite supply of oxygen for the smoke, instead of applying it already heated. Introduced by our method through

ingeniously contrived apertures, which cause gyrations better understood in actual experiment than by any attempt at description, time is allowed for the air to mingle with the carbonic oxide to saturation, and the gasses retarded within and under the boilers, are ignited and inflamed before reaching the end of the tubes. There can be no doubt but near one-half of the oxygen passes through our common furnaces without entering into combination with the carbon and hydrogen in the fuel. Every pound of coal requires two pounds of oxygen for its saturation ; but owing to the rapid draughts of furnaces in general, about four pounds of oxygen for every pound of fuel consumed, passes through the furnace. By the slow and perfect combustion under our method, the flame is kept abundantly supplied with oxygen, and sufficiently retarded for all the useful particles of the fuel to be applied to the generation of heat.

The good effects of slow combustion, in combination with our method of introducing air already heated, in preserving the iron surfaces of the furnaces, has been already mentioned in a former connection. It is believed to be a scientific conclusion that the flame, when perfectly ignited, is less detrimental to the metal than that which has not been as completely purified. We entertain no doubt, that the usual average of engines under repair in the machine shop, often estimated as high as one out of every five, will be much reduced by the introduction of our system. Curves, which had been subject for months to the most intense heat, were found not to have been diminished in weight or strength. So much was the Belgian Minister impressed with this unexpected result, that at his desire these curves were sent to Belgium, where they now are. They have our furnaces already in that country, are testing the principle in stationary boilers, and are about to apply it to puddling and house furnaces, and also to Locomotives.

Another important advantage resulting from slow combustion is the greater control over the fire. Upon closing the damper the evaporation is more immediately checked, and this is on many considerations of great value upon the road and in the station, or round house. Nor should another decided recommendation in its favor be overlooked, in the great saving of labor to the fireman, from the less frequent renewals of the fuel.

Surprise has been expressed that if these suggested improvements in the arrangement of furnaces possess the merit that we claim, it should not have been more generally recognized, and these improved constructions universally adopted. Reasons

enough might be readily suggested why this backwardness ought not to work to our prejudice. Besides the usual obstacles attending all attempts to innovate upon established systems, others have been presented peculiar to the subject or to our own condition. The theory of combustion is not only not familiar, but often irksome to those who from their position would be called upon, in case of any great alteration of the usual modes, to assume the responsibility. What has also operated much to our disadvantage has been want of capital for the trial of experiments, for plans and models, and other means of recommending our system favorably to public notice. We have had, moreover, to conquer prejudices, to compete with rivals, and the very simplicity of the principles upon which our system is founded has possibly attracted less attention to its claims than it deserved. It is no easy task to overcome the resistance of fixed opinion, most frequently found among the least informed; but we have had to contend with the theory of the scientific and the practical objections of engineers, both alike reluctant to admit truths upon the most conclusive evidence when at variance with preconceived ideas. The endeavors heretofore made to improve locomotives have commonly been directed to other parts of the machine; and much time and labor fruitlessly wasted, which might have been more wisely devoted to the motive power, the proper use of fuel.

But if, during the years of toil and anxious solicitude, employed in maturing our system of economical combustion, much has been met to dishearten, a lively sense of gratitude is felt towards the many whose cheering encouragement induced us to persevere. To several of these distinguished for great scientific attainments, every acknowledgment is due for their patient attention to the explanation of our views and generous aid in ascertaining their merit. While ever ready to devote their time and services to what might possibly conduce to the public benefit, they did not hesitate when convinced we were right in our system to pledge their great reputation by the most ample certificates to its support.

We would also acknowledge the wise liberality of the management of the different railroads for facilities afforded in testing our improvements. On the Lowell road, permission was given to adapt our curves to an ancient engine, which had been running for twenty-two years, and was about to be broken up owing to the weakness of its boiler. The attempt to run her, when altered, to Lowell, was deemed exceedingly hazardous, and the

superintendent himself did not care to venture upon the trial. Most satisfactory, and it may be said, startling results were obtained in the perfect freedom from black smoke, and the saving of quite half the fuel, with all the speed and power required.

In consequence of this success, Judge Hopkinson, the late much lamented President of the Boston and Worcester Railroad, invited us to try our experiments upon his road, and ordered a twenty ton freight engine to be appropriated for the purpose. This, after some disappointments, was accomplished, and the Hecla with the curves and feeders yielded results which, as presented in the report of Mr. Nott, her engineer, and in the deductions of Mr. Hale, than whom no one has more familiarity with all subjects, connected with railroads, show a saving of sixty-two per cent. over the average of freight engines the year preceding. Although in consequence of his removal by Providence from his useful career, no official report was made by the President, there is every reason to believe that that ordered by those left in power upon the road will be appreciated, and full justice eventually done to the merits of our system. As will be seen by this report, strict inquiry was made as to every particular during the experiments. Many thousand miles were run by the engine in the winter of 1855–6. Her fuel, Cumberland coal of an inferior quality was taken in the morning and lasted all day. The records will show that she assisted in snow drifts, helped the disabled, and carried the average loads under the severity of a remarkable winter. She was used for the testing of the experiments, and this operated partially to our disadvantage.

Some trials were made of our inventions at the Navy Yard at Washington, but not under circumstances affording any test whatever of their value. A writer in the Franklin Journal, commenting upon these experiments, with some severity, had the candor to admit that, if we could reverberate the flame, and burn the gases, as pretended, we would doubtless effect the saving. The answer to this, in the following number, was sufficiently laconic and to the point. It was simply a certificate of the Hon. Nathan Hale, John H. Blake and Thomas A. Dexter, stating that they had actually seen, at the Navy Yard at Charlestown, that we could reverberate the flame, mix the gases and burn the smoke. In order to subject this to occular demonstration, a glass window had been inserted in the furnace, and this interesting process can still be any day witnessed by a visit to the Navy Yard.

For efficient railroad management exact rules and methodical system are indispensable, and experiments, interrupting the regular routine of employment are attended with some incon venience. But with the present intense competition, dividends can only be realized by the most rigid economy; and it is the obvious duty of those, intrusted with the interests of their stockholders, to carefully investigate proposed improvements, presenting reasonable promise of promoting this desirable consummation. A small annual per centage of economy in fuel upon our railroads would amount to a vast sum in the aggregate. The expenditure of a few thousands in experiments cannot be injudicious where millions may in consequence be saved. Should the outlay be an unreasonable burden for any one company by combination and distribution it would not be felt. It is all important that the trials should be made under the constant supervision of some one alike scientific and practical.

After the repeated assurances of those most competent to judge of the value of our improvements, and constant experiments fully confirming their favorable conclusions, we cannot doubt but that our system ought to be generally adopted. If, however, any other construction should be found, predicated upon other principles, better entitled to consideration, we are of course not sufficiently selfish to willingly stand in the way of the immediate adoption of what must so greatly enure to the public benefit. Whatever the issue, we shall be pleased to have labored vigorously for a good cause, and should it be success, have the satisfaction of feeling it was not earned without effort.

JONATHAN AMORY,

In behalf of the Franklin Locomotive Company.

MR. NOTT'S EXPERIMENTS

WITH THE

LOCOMOTIVE "HECLA,"

USING CUMBERLAND BITUMINOUS COAL,

DURING THE TRIALS INDICATED BY TABLE NO. 1.

BOSTON AND WORCESTER RAILROAD.

In noticing the mode used during these trials with the Hecla it must be kept in view that in the introduction of the raw coal much of the disengaged portions are suddenly carried to the shell chamber, and there, after being somewhat cooled, directly to the tubes and smoke stack. This light material gradually forms a coating on the tubes which experience thus far plainly indicates must be removed before a true efficacy can be produced.

The experiments upon the Hecla, when using the mode indicated by the sketch, were tried with the greatest care to gain a fair result of the use of coal by first putting the raw material into the fire box, and then conveying the escaping portions into a chamber more nearly in contact with the water surfaces. In using coal by this plan there appears to be two simple causes for failure. One which arises from the non-combustion of fuel which escapes even from the intense heat of the fire-box, and the other from a loss of heating surface. The unconsumed particles immediately passing to the shell and tubes while n the form of smoke and bitumen, on reaching these comparatively cool places become partially condensed while the condensing process is in part carried out, there is a heaviness, so to speak, produced

in the chimney by portions of the exhaust steam becoming mixed with, and adhering to the already troublesome way from the fire box, which retards the egress of the steam from the cylinders. This effect can be seen when raw coal is added to the fire. There is then a decided falling off in the steam, and apparently more effort in the working of the cylinder motion. This trouble would be obviated by a more thorough combustion. The exhaust is obliged to force through the tubes the products of a poor combustion, which is another tax on the efficiency of the locomotive.

When the mixture with raw coal is not good (and air) there is always a very black and cloudy appearance in the fire box. This, on its first movement, after passing over the heat and up to the top of the box to the chamber, then goes directly to the tubes, which carry the heat and fuel through them in a column.

By this plan the direct draft sweeps the chamber, and carries the sparks and the body of smoke to the chimney in large quantities. To examine the use of white pine wood used upon a locomotive, and then carry the examination along through the different kinds of wood to the most pitchy and then from this to the use of bituminous coal, then one would at once see the reason that there are so many failures to produce an economical efficiency in the use of this kind of coal. They all come from a wrong use of time to create a clear heat from the raw coal.

Steam can be made on any wood burning locomotive by using bituminous coal and in the same abundance as it would with wood, but it cannot be done without wasting a large part of the fuel, and producing other results which would of themselves make a total failure. The repairs would be very much increased, and there would be thrown from the chimney a cloud of smoke and sticky bitumen which would be a nuisance from one end of the road to the other. Such was the effect from the mode first used on the Hecla during the trials but not to that degree.

The use of the "Hecla" on a freight train produced hardly so good a result as on a passenger train. As the tendency on the slow train is to roll over into the chamber in the shell carrying the cloud to the tubes and chimney. When used on a passenger train the bed of coal is more ignited, which on entering the chamber produces a better first effect, but when there is any raw coal added, and when the train is stopping the effect is the contrary. The entrance of the air under the furnace, the shell, and next to the water surface, is decidedly to cool and condense the volatile fuel.

During these trials there was but little stopping, or but little leaving or taking cars on the road. The doors of the fire box were partly opened after the new coal was added during these trials in order to lessen the bad effect of smoke.

The conclusion is that the mode made use of in these trials does not produce efficiency, the contracted space of the shell room of a boiler cannot be used. Efficiency must come from a clean heat produced elsewhere. In using the coals in this mode the effect is to some extent the same as if it were used on an ordinary locomotive.

SECOND TRIAL.

The Hecla on this trial was used by the mode adopted by the Franklin Locomotive Company. Their plan is to gain time for mixture and combustion to produce a clear heat, thus to overcome the hitherto poor use of pitchy wood or bituminous coal.

The time is gained by producing eddies, thus making the unconsumed fuel travel further and use more time. This is done in the shell of the boiler by cutting off the tubes and placing the curves in the chamber, but located here they produce an effect contrary to that they would if the heat was more intense, and not exposed to the cooling effects of the surface next to the water.

These trials point out distinctly what course may be followed with a fair chance of ultimate success, and which would, if properly followed, assist very much in the introduction of bituminous coals with the everyday use of locomotives. From these experiments it appears that to produce the highest effect by this plan it is not best to introduee unconsumed fuel into the shell, for here the heat is not so intense as it is in the fire box. If the mode can be used within the fire box itself this plan may be of great use to Railways. There are indications that there is not time for mixture in the present fire box, as the light unconsumed fuel is rolled into the tubes from off the intense heat, coming up from the ignited fuel before the thoroughly heated air can come through the fire and mix. The combustion is carried from a good place to one where, if time is gained, it can be of little service. Any plan having for its object to produce a clear heat, that is a heat that may be used among the tubes without injury to them, either by retarding gasses or by coating, is one that railways cannot pass by without a patient examination.

The delay in combustion caused by this plan used during these trials is apparent upon an examination of the unconsumed fuel in its passage through the chamber, but this apparent gain is neutralised by continual condensing of the residium, and a very large loss in heating surface. Much of the sticky, sooty substance is held up among these eddies after leaving the fire-box, making a barrier here to the introduction of sufficient fuel to produce efficiency. If more time could be gained for combustion in the intense heat of the fire-box, experience in the use of fuel for locomotives shows plainly that less fuel will be used to produce the same effect. The leaking of the tubes is more generally owing to the residuum of a poor combustion passing through them from the fire-box to the intensity of the heat.

To give a true application of fuel the combustion must be carried on as far away as possible and practicable from the water spaces as they are decided condensers. Fuel is not made useful after it enters the tubes, but on the contrary is a damage as before shown.

The fire was not managed with the same care as it was during previous trials. There was not as much effort to clear the clinker from the sides and the grate bars. In the first four trips, the coal was of a very inferior quality, as well as being more than ordinarily fine; upon the remaining trials, the coal was large, and of a better quality, although there was some large lumps with veins of slate. During these trials, there was a large portion of the time used in taking and leaving cars at the stations on the road, which required more fuel than if the train went over the road without changing.

The furnace door was not opened after firing, and the smoke from the chimney was quite light colored. There was an instant after the raw coal was added when there was a cloud from the chimney, and this was not very black.

The injurious effect in the use of coal instead of wood on a wood burning locomotive must be avoided before coal can be used with success. These trials show that much better results than those here given can be obtained if any plan can be applied to a wood-burning locomotive, by which the advantage of the time gained for combustion by this plan could be maintained, and the experience in the use of bituminous coal thus far gives great hope of success. The conclusion derived from the two trials is that coal cannot be used economically when separated from the principal fuel chamber, and not even there unless more time is gained for the necessary mixture of the products. Experience shows that the best way to gain efficiency is to allow nothing which acts as a cooler to come in contact with the fuel. This can hardly be carried out upon a locomotive, but the nearest approach to it is the true aim. Economy of fuel in any locomotive depends much upon the skill and degree of attention exercised by those who use it. I have been much assisted in forming opinions here expressed by other experiments both as to wood and coal now in progress. These trials and others of a like kind tend to show that there may be a mode by which the greatest economy can be obtained in the use of coal by cheap alterations of the present locomotives. In building new locomotives, with a view to the use of such a mode, some new features could probably be introduced, which would much facilitate the working of the plan.

Upon the subject of anthracite coal, I made some enquiries two years ago in the Schuylkill region. The injury to the parts in contact with the intense heat was very evident from the use of the coal. The cause is found in the fact that there was much disengaged fuel in the shape of gasses.

If railway companies could be induced to carry on jointly practical examinations entirely free from the influence of interested parties the best of results would in time follow.

G. H. NOTT.

EXPERIMENTS

On the Plan of the Franklin Locomotive Company, with the Locomotive Engine "Hecla," using Bituminous Coal, on the Boston and Worcester Railway, in May, 1856.

Starting from.	*Distance, miles*	*No. of 4 wheel cars*	*Weight of train*	*Wood kindling used per round trip*	*Coal used per round trip.*	*Water used per round trip*	*Coal used, up or down*	*Water used, up or down.*	*Time used on road*	*Number stops*	*Average pressure*	*Cubic feet cinders*	*Cubic feet sparks*	*Water evaporated to one pound fuel*	*Water evaporated per hour*	*Cost per mile in cents and parts*	*Remarks and Explanations.*
			lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*h. m.*		*lbs.*			*lbs.*	*lbs.*		
Boston,...	44¼	26	369,000	3105	4810	30,911	2620	16,364	4 40	7	72	9 9	4 9	6.07	3914	19.01	Stopped on Natick Hill for want of steam.
Worcester,	44¼	30½	319.000				2190	14,547	3 43	6	65	9 5	4 8	6.42	3506	16.09	
Boston....	44¼	24¼	312,990	2270	4190	26,777	2590	16,531	6 06	8	59	11 3	5 6	6.24	2710	18.62	Exhaust-variable on first four trials, fixed on all the others.
Worcester,	44¼	18	189,990				1600	10,246	4 11	6	59	8 8	4 5	6.18	2449	11.82	
Boston,...	44¼	35	399,900	2940	3800	27,420	2200	16,841	4 31	6	70½	8 9	2 4	7.40	3728	16.21	
Worcester,	44¼	10	129,090				1600	10,579	4 04	7	70	8 9	2 8	6.32	2601	11.98	
Boston,...	44¼	23	269,900	2116	5198	38,355	2398	16,531	4 39	7	85	7 5	4 9	6.75	3514	17.43	
Worcester,	44¼	35	419,000				2800	21,824	5 02	8	61	8 1	3 8	7.65	4336	20.27	Helped 2d fr'ght around curves. betw'n Brighton and Newton.
Boston,...	44¼	34	370,000	2550	4200	32,743	2610	19,519	4 31	8	79	9 4	3 8	7.30	4321	19.05	
Worcester,	44¼	22	239,000				1590	13,224	4 09	8	85	8 1	4 9	7.99	3187	11.90	More than average amount of changing cars at Brighton.
Boston,...	44¼	38	420,900	2257	4355	36,442	2980	24,870	5 49	8	65	6 5	3 3	8.20	4277	20.92	
Worcester,	44¼	23	199,000				1375	11.571	3 51	7	72	7 1	5 1	8.08	3005.5	10.24	Helped the 2d train a little beyond Millbury Depot.
Boston,...	44¼	27	349,900	2257	3737	25,459	2295	15,206	4 07	4	73	7 3	2 8	6.46	3694	17 13	
Worcester,	44¼	15	189,090				1442	10,253	3 56	5	82	8 1	2 7	6.84	2606	10.71	Pushed 2d freight train from Grafton to the "By-Ledge."

DEAR SIR: —I now send my Report on experiments on the Boston and Worcester Railway. It has been delayed somewhat, in order to gain as much information as possible, applicable to the subject from other like experiments which I have now in progress.

Very Respectfully Yours,

GORDON H. NOTT.

HON. THOMAS HOPKINSON, *Pres't Boston and Worcester R. R.*

COAL AS A SUBSTITUTE FOR WOOD,

IN LOCOMOTIVES.

EXTRACT FROM HON. NATHAN HALE'S REPORT,

[PUBLISHED IN BOSTON DAILY ADVERTISER.]

The following statement of the result of the experimental trials therein described, made on the Boston and Worcester Railroad, for testing the efficacy and cost of coal, in comparison with wood, in producing steam for the transport of freight trains on railways, was made at the request of persons desirous of ascertaining the success of those trials. Believing that there are many other persons who take an interest in the subject, we publish the statement for the information of such of our readers as may be disposed to investigate it, believing on our part that the question involved in the inquiry is one of great public importance.

The experiments superintended by Mr. Nott, of the performance by the Hecla, which furnish the facts for a part of the statement, are reported by him in detail, and with great precision and minuteness of calculation. The comparative statements are the results of our computation, based on the data furnished by those reports, and by the official return of the operations of the road during the last year, made to the Legislature by the Directors.

Cost of Fuel on the Boston and Worcester Railroad, in the year 1855; *and Experiments for testing the success of coal-burning Engines in reducing the cost.*

In the year 1855, the number of passengers transported one mile, was	25,736,825	
Weight of passengers and baggage, estimated at 200 lbs. each,	2,573,682	tons
Weight of passenger cars,	20,340,662	"
Total weight of passenger trains,	22,914,344	"

Weight of merchandize transported,	12,056,959	tons
Weight of freight cars,	16,652,790	"
Total weight of freight trains,	28,719,749	"
Miles run by passenger trains,	341,791	
Miles run by freight trains,	187,243	
Miles run by gravel and other trains,	12,414	
Total,	541,448	
Cost of wood for all trains,	$151,476	
Deduct for gravel trains,	3,463	
Fuel for passenger and freight trains,	$148,013	
Average of passengers per train,	75.3	
Estimated weight of passengers with baggage,	7.53	tons
Weight of passenger cars per train,	59.52	"
Average weight of passenger trains,	67.05	"
Average weight of merchandise, whole distance of each train,	64.46	"
Average weight of cars,	89.	"
Average weight of whole train,	153.46	"

To make an accurate division of the amount above, computed as the cost of fuel used on the two classes of trains, in proportion to the quantity consumed on each, we must increase the number of tons weight transported one mile in the passenger trains, by about 12½ per cent. on account of their greater speed, and the more frequent stops of the accommodation trains. The number thus increased, compared with the actual number of tons carried one mile by the freight trains, will furnish, as nearly as it can be ascertained, the proportion in which the sum of $148,113, expended as above stated, should be divided between the two departments. Such a division gives $69,553 for the expenditure for fuel on the passenger, and $78,460 for that on the freight trains.

The sum of $69,553, divided by the number of miles run during the year by passenger trains, shows that the average cost of fuel per

mile for those trains, amounted to 20.35 cents. The same sum divided by the number of passengers carried one mile, shows an average cost of 27-100 of a cent per mile; and divided by the tons weight of trains shows an average cost per ton of 303-1000 of a cent per mile, exclusive of the weight of engine and tender.

The sum of $78,460, divided by the number of miles run by the freight trains, shows the average cost of fuel to have been 41 9-10 cents per mile of each freight train; divided by the tons freight carried one mile, it shows a cost of 65-100 of a cent per mile; and divided by the entire weight of trains transported one mile, shows a cost of 273-1000 of a cent per ton of the load and dead weight moved.

Taking the results of this computation of the cost of fuel *consumed on the freight trains on the road* during the year 1855, founded on the official returns of the business of the year, as showing the rate of that branch of expenditure, at the present time, by the use of wood-burning engines, we have a basis of comparison by which to determine whether any saving of cost can be made, by the substitution of bituminous coal.

Having had an opportunity of cxamining Mr. G. H. Nott's report of the experiments superintended by him for testing the efficiency of the engine Hecla, I have made the following statements of the results of those experiments, for the purpose of presenting them in a form which will admit of a ready comparison of them, with those afforded by the wood-burning engines.

To these statements I have subjoined such remarks as seem to be necessary for bringing into notice the difference of circumstances under which the results in the several cases were obtained.

For the purpose of ready comparison, I here recapitulate the prominent results, beginning with the computation based on the year's operations, and followed by those based on the experiments for burning coal.

1. *Wood-Burning Engine. Average of* 1855.

Weight of train, average both ways,	153.46 tons.
Tons 1 mile per trip,	6,828
Cost of fuel, per trip of 44½ miles,	$18.69
Cost of fuel, per mile of each train,	41.9 cts.
Cost of fuel, per mile of do.,	0.273
Cost of fuel, per ton of goods, do.,	0.576

(*See Note A.)*

2. *Coal-burning Engine Hecla, with Baker's Curves.*

Weight of train, average both ways, ... 149.16 tons.
Tons 1 mile per trip, ... 6.637
Cost of fuel per trip of 44½ miles, with wood for kindling, $7.01
Cost of fuel per mile of each train, ... 15.75 cts.
Cost of fuel per ton per mile of do., ... 0.1056
Pounds of coal and wood per trip, ... 2288 lbs.
Pounds of coal and wood per mile of train, ... 51.4 "

(See Note B.)

3. *Coal-burning Engine Hecla, without Baker's Curves.*

Weight of train, average both ways, ... 194.1 tons
Tons 1 mile per trip, ... 8,637
Cost of fuel per trip of 44½ miles, with wood for kindling, $10 18
Cost of fuel per mile of each train, ... 22.87 cts.
Cost of fuel per ton per mile of do., ... 0.197
Pounds of coal and wood per trip, ... 3371 lbs.
Pounds of coal per mile of train, ... 75.5 "

(See Note C.)

Note A. The amounts stated under this head show the average results of the freight movements of the last year, modified by all the contingencies of the season—of irregular business and deficient loads in either direction—it frequently happening that when there are the fullest loads in one direction, there are the most empty cars in the other. This accounts for the average load being far below the capacity of the engines to carry, and far below the average of full loads actually carried. Such must always be the average result of the regular business. It accounts also for the excess of the average cost per ton of the weight transported, over that of a full load on an experimental trial.

Note B. The statements of the performance of the Hecla are deduced from the report of Mr. G. H. Nott. The engine as fitted up under the direction of Mr. Amory, on the principle of Baker's furnace, with air pipes to aid the combustion, was employed to perform the regular duty of the third morning freight train from Boston to Worcester. As a part of that duty the train was charged with the reception and delivery of merchandize not only at the termini of the road, but at all the way stations, whenever occasion required.

I am unable to say how nearly the duty assigned to it corresponded with the average of ordinary trains, embraced in the foregoing statement; but I infer from the fact that the two first regular morning trains do not ordinarily stop at way stations, except for the taking of water, it must have been subject to more than the average inequality of loads, and much more than the average amount of delay. It appears from the time-table for the regulation of the trains on the road that 4¼ hours are allowed for the "first freight train," including a stop at Framingham to allow the going ahead of the passenger train. This allowance of four and a quarter hours, I understand, is intended to afford time, in ordinary cases, for not only the first train, strictly speaking, which leaves Boston at 4.45 A. M., but two or three supplementary trains which follow it with a red flag, to arrive at Worcester — the ordinary regular time for the trip of each being reckoned at four and a quarter hours. No other train, however, according to the time-table, is entitled to the road until 11 o'clock, making 5¼ hours from the departure of the first freight train No. 1. This is doubtless designed to make provision for usual delays on either train, and especially on the third, which stops at the way stations. The Hecla, on the trips recorded, took the place of freight train No. 3. Mr. Nott reports the time occupied in each trip, and the number of stops, but not the running time or the duration of the stops. I find by computation from his statement, that the average duration of the upward trips was 4 hours 54 minutes, and of the downward, 3 hours 53; and the average of stops was about 7 to each trip. I infer from information from him, that the loss of time on these trips was not less than an hour to each, leaving less than four hours for the average of running time on the upward trips, and less than three hours on the downward. It would seem reasonable to infer from these facts, that in regard to time, the performance of the Hecla, used as a coal-burning engine, was equal to what it would have been, had she been running without alteration, and with wood for fuel. It appears from Mr. Nott's report, that in three of her upward trips, she overtook and assisted the wood-burning engine which preceded her — once on the steep grade in Brighton, and twice on the long ascending grade near Worcester. In regard to the weight of loads, it will be perceived that the average was but three per cent. below that of all the trains of last year; and that she drew without difficulty all the loads which were assigned to her, except in one in-

stance, on the first downward trip on the most difficult ascending grade, when working with very inferior fine coal, unfit for the purpose. The trip was nevertheless made without assistance in less than four hours.

NOTE C. The experiments on the Hecla without the curves of Baker's furnace, were made without Mr. Amory's advice, on the supposition that with the introduction of the air tubes, the efficiency of the engine might be greater without, than with them. The trial proved the contrary; for although the engine carried heavier loads by 31 per cent., she consumed more fuel by 45 per cent.; and occupied a greater average time in the trips, while she made but half the number of stops, having occupied the place of No. 2 of the morning freight trains, instead of No. 3. It thus appears to show that the reason why the Hecla did not carry heavier trains in the trial with Baker's curves, was that sufficient loads were not put upon her to test her power. This is further proved by the greater quantity of water evaporated, in proportion to the quantity of coal consumed, which, according to Mr. Nott's report, amounted with the curves, to the unusual proportion of 6.99 lbs. of water to one of coal, and without them to 4.62 lbs. only, on an average of the fourteen trips in one case, and of twenty-two in the other. This shows the completeness of the combustion of the coal, and its effect on the boiler, more accurately than the quantity and distance of load transported, because we have no accurate measure of the delays of trains, and consequent loss of any productive effect from the steam generated. The proportion of water evaporated on the fourteen trips, is a very unusual quantity for a locomotive, rarely exceeded, even by coke.

Mr. Nott's report affords also another conclusive proof of the more thorough combustion of the coal with the curves than without them. I refer to the enormous quantity of sparks and cinders intercepted by the sparker, and collected in the cap outside of the chimney. These sparks are reported as amounting, in the trials without the curves, to an average of 12 2-3 cubic feet per trip. Besides this amount collected by the sparker, there was a further quantity of cinders accumulated within the chimney, amounting to an average of six and a quarter cubic feet in each trip. The sparks collected by the sparker, on the trips with the curves, amounted on an average to a fraction over four cubic feet, instead of 12 2-3, and the cinders within the chimney to 8.4 feet, instead of 6 1-4. This difference in the amount

of sparks shows a great advantage from the curves; and it remains to be seen whether this beneficial effect may not be greatly increased by merely placing the fire-grate higher and nearer to the boiler, and by introducing heated air for supplying the combustion beneath the grate, by tubes passing under the curves, as is done in the stationary boilers at the blacksmith's shop at the Navy Yard in Charlestown.

It may doubtless surprise persons not conversant with the number of empty or half-loaded cars necessarily transported, for meeting the irregularities of the freight business, to learn that the average loads bear so small a proportion to what the engines employed are capable of carrying, and that the available load is in so great a disproportion to the dead weight. The amount stated above as the average of the loads carried by all the trains of the Boston and Worcester road, during the year 1855, although considerably less than the average of the preceding year, was greater than that of any other railroad in the Commonwealth, as will be seen by the following statement of the average weights of trains on the principal freight-carrying roads, for the year 1855, viz: —

	Merchandise.	Dead Weight.
Boston and Worcester,	64.4 tons	153.4 tons.
Western,	55. "	not reported.
Boston and Lowell	52. "	124. tons.
Fitchburg	52 4 "	136. "
Boston and Maine	53.4 "	152. "
Boston and Providence	50.7 "	163. "
Old Colony	49.7 "	101. "

The reason of the greater than average proportion of dead weight on the Providence road, is probably that it carries a larger proportion of measurement and light goods, and a similar cause may have affected the comparative weight on other roads. This statement will show how far the average of loads necessarily carried, falls short of what perhaps every engine employed would be capable of carrying on a trial trip, loaded for the purpose, especially if it could find a full load for the return trip. It shows, also, that if a trial trip is relied on for testing the capacity of an engine, care should be taken that the load correspond as nearly as possible with the average of regular business, or that in forming a judgment of the comparative value of the results, a just allowance should be made for the difference of circumstances likely to occur on other trials which would materially change those results.

In presenting this statement of a mathematical analysis of the results satisfactorily authenticated, to aid those who are desirous of forming a judgment of the relative efficacy of the new modes of producing steam power on locomotives, I feel bound to state my entire incompetency to form any satisfactory judgment, from my own observation of the success of either of the modes which have been subjected to the tests in question. I haye for this reason confined my remarks on this question to the results of the experiments made as reported from actual measurement. I have in fact had no opportunity to make such observation of either, except to a very limited extent, viz , in making a single trip some months ago on the Lowell railroad, in a passenger car attached to a light freight train drawn by an old engine fitted up with Baker's curves, under the direction of Mr. Amory. The experiments appeared to me promising, in the apparent thorough consumption of the coal and consequent prevention of smoke, except occasionally to a very limited amount; and in the small quantity of coal used to draw the load. But the boiler was not considered safe for putting upon it such an amount of steam as would satisfactorily test the efficacy of the mode of heating.

I have long been of opinion that it was becoming imperative on those entrusted with the management of railroads, to resort to coal in place of wood for locomotives, either in its crude shape or in the form of coke, and I have given a good deal of attention to the modes of doing it. Anthracite coal seemed at first promising, but it was long ago demonstrated to my satisfaction, that it was entirely unfit for the purpose, unless on heavy freight trains, running uninterruptedly long distances. Free burning bituminous coal, like the Cumberland, is much better adapted, if it can be made to consume its own smoke and cinders. This object seems to me to have been in a good degree attained in Baker's stationary furnace, and the heating power of the coal is thereby much increased. The experiments made by Mr. Amory go far towards demonstrating, if they do not fully prove it, that the same effect may be produced in the locomotive. The experiments on the Hecla, of which I have here given an analysis, I think prove satisfactorily, so far as the producing of a steady heating power is concerned, that the object is attainable at about half the cost of wood, on the Boston and Worcester road.

NATHAN HALE.

Boston, Sept. 6, 1856.

A PAPER

READ TO THE

AMERICAN ASSOCIATES

FOR THE

ADVANCEMENT OF SCIENCE.

The undersigned, a committee appointed by a number of the manufacturers of New England, to examine "Baker's Improved Boiler Furnace," and to investigate the advantages claimed for it, with a view to ascertaining how far they are well founded, submit the following report: —

The peculiarity of this invention consists in one, two, or three inverted arches, according to the length of the boiler, which are placed behind the fire, transversely under the boiler, leaving a space between the external surface of the boiler and the top of the extremity of the arch nearest the fire, of about four inches; the other extremity of the inverted arch, and the succeeding arches, are so constructed that each successive opening or flue is diminished in width, in such manner that the most distant is reduced to about two inches in depth. The extremities of each inverted arch are curved in such manner that the flame, smoke and hot air, in passing from the fireplace, after being forced into close proximity with the boiler in the narrow space, are reverberated on the opposite side of the inverted arches—the combustible gases are brought into contact wtth the flames, and are burned; while the incombustible gases, being heavier, fall below, where they do not interfere with the process of combustion, which thus becomes as nearly perfect as possible.

This is an outline of the improvement of Col. Baker. An important addition has recently been added by Mr. Amory. No air is admitted to the fire in front, but it is fed from a chamber connecting with the outer air near the chimney, by means of a tube leading thence to the space below the fire-grate. This tube is so placed that the air in its passage through it acquires a considerable degree of heat, whereby the combustion is aided.

The whole apparatus is now owned and applied by the Franklin Locomotive Company. On account of the convenience of a simple designation, we use the name "Baker's Furnace," in this report instead of any other. Indeed, all of the experiments here detailed were made before the addition of Mr. Amory's flue, which is found to increase the efficacy of the Furnace, and thus presents results more favorable than those described.

It might not be difficult to explain in theory the advantages which *must* result, in the perfect combustion of the fuel,—the close proximity in which the heat is brought to the boiler. But we will merely allude to the supply of the furnace with air partially heated—the retardation of the current of flame, smoke and gases emitted from the fire-box, and the commingling of the various ingredients by reverberation of the compound mass from opposite sides of the inverted arches and the bottom of the boiler, whereby the different elements are brought into contact, and more time is given for evolving the heat, and for consuming the combustible material which otherwise would be discharged from the chimney—as constituting the prominent advantages which are secured by this invention. Instead, however, of discussing the subject from a theoretical point of view, the committee prefer to examine the practical operation of the Furnace as tested by numerous experiments which have been carefully made, and the results regularly recorded.

The first series of experiments to which we shall allude were made by Messrs. Richmond Jones, Jr., and Charles S. Homer, Jr., of the Lawrence Scientific School, Harvard University; these gentlemen having been designated by Professor Horsford and Eustis for the purpose. They experimented at the Neponset Mills in Canton with and without Baker's Furnace, the experiments lasting several days. One of them remained on the spot during the whole time, both day and night, to prevent the possibility of any error. Every charge of water and of coal was carefully weighed; the time at which water was introduced to the boilers, or coal into the furnaces was noted

and also the temperature of the air in the boiler-room, and the length of the interval that doors were opened. The whole experiment was conducted on the most elaborate scale, and the results noted were the greatest precision in complete tables which have been published or the information of those disposed to investigate the subject.

The deductions derived from the most elaborate of these experiments may be briefly summed up as follows; in the test by the evaporation of water, with Baker's Furnace, in the quantity of coal consumed during a period of 48 hours was equal to an average of 50 85-100 pounds an hour; without Baker's Furnace, the quantity of coal consumed in the same period was equal to an rverage of 75 958-1000 pounds per hour—the quantity of water evaporated being very nearly the same. Advantage in favor of Baker's Furnace, 49 per cent; the ordinary furnace requiring the consumption of an increased quantity of coal in that proportion to produce the same result.

It should be understood that by experiments made "with" and "without Baker's Furnace," we mean experiments all made by the use of the same boiler, furnace, grate and other apparatus of every description, with the single exception that those "without Baker's Furnace" were made with a furnace constructed in the ordinary way, as the same had been in use for the work of the mill; while those with Baker's Furnace" were made after the same furnace and boiler had been fitted up by the insertion therein of the inverted arches, described in Baker's patent, without any other change whatever, and without the tube for feeding the fire with warm air, which is an improvement since added by Mr. Amory.

The saving of fuel in the proportion of 49 per cent. is certainly a consideration worthy the attention of every establishment where a considerable expense is incurred for coal. In this connexion we present the following letter from Noah Butts, Esq., Engineer at the Navy Yard, Charlestown, where there are twelve boilers set with Baker's Furnaces, to each of which boilers Mr. Butts says five hundred pounds of coal are fed per day. By the above figures, it appears that seven hundred and fifty pounds would be required to do the same work without Baker's Furnaces. The saving in a year is thus shown to be a very handsome sum.

The following is Mr. Butts' letter:—

J. Amory, Esq., Dear Sir—We have 12 boilers set on your plan at the Boston Navy Yard with Baker's furnace; and they continue to give satisfaction, burning, say 500 lbs. of coal to each boiler. At this rate we have saved a great deal of coal, some hundreds of tons each year. It is the more remarkable, as our boilers were as well set as any stationary boilers before your plans were introduced.

Noah Butts, Engineer.

Navy Yard, Aug, 13, 1855.

We shall next allude to the Report upon Baker's Furnaces, made in England by a most eminent engineer, Thomas Wicksteed, honorary member of the Royal Cornwall Polytechnic Society, than whom no higher authority can be cited on a question of this sort. He had of course no prepossessions in favor of the American invention. He made his experiments with the greatest care, comparing Baker's Furnace with some improved furnaces, by which a great saving over the ordinary furnaces was already gained; so that Mr. Wicksteed, with great fairness, before undertaking the experiment, told the agent that "he must not expect the saving, if any, to be at all equal to that obtained by the introduction of the new (Baker's) Furnace into works of the ordinary construction." This we quote from Mr. Wicksteed's own report. The experiment was made with the poorest quality of bituminous coal.

Mr. Wicksteed's experiment with Baker's Furnace lasted 108 hours; with the other improved furnace 207 hours. Baker's Furnaae in 108 hours consumed 31,651 pounds of coal; the other furnace in 207 hours consumed 64,940 pounds of coal.

The weight of coal consumed per hour by Baker's Furnace was 293 pounds; by the other furnace, 313 pounds. Advantage in favor of Baker's Furnace, 7 per cent.

With Baker's Furnace, 8 640-1000 pounds of water were evaporated from boiling point for every pound of coal consumed; with the other furnace, 7 725-1000 pounds. Advantage in favor of Baker's Furnace, 12 per cent. Or in the usual mode of computation, the rate of saving of coal by the use of Baker's Furnace, was 14 2-10 per cent. on the quantity used.

With Baker's Furnace, 9 273-1000 pounds of water were evaporated from boiling point for every pound of fuel actually consumed; this result being obtained by deducting from the weight of the coal fed to the furnaces, the weight of the clinkers and ashes remaining

unconsumed; with the other furnace, in the same way, 8 217-1000 pounds of water were evaporated. Advantage in favor of Baker's Furnace, 12 3-10 per cent.

This percentage of saving in comparison with the improved furnaces against which Baker's Furnace competed, seems to justify the results of the other experiments in comparison with the ordinary furnaces. This is admitted by Mr. Wicksteed, who says, "I can have no hesitation in declaring that the saving of 37 per cent. upon the average, stated to have been effected in the American establishments, has been effected."

Mr. Ericsson, in remarking upon this report, says of Mr. Wicksteed, that "he is a man remarkable for accuracy and system on all matters relating to engineering — so much so, that on a practical subject like Col. Baker's Furnace, *I would submit to his decision in preference to that of any other engineer in England.*"

The New England Association of Engineers appointed as a committee to make experiments for testing Baker's Furnace, Messrs. Simeon Borden, William P. Parrott, and Samuel Nott. Under the direction of these gentlemen, two elaborate experiments were made at the Linseed Oil Mill, in East Boston, each of which was continued through forty-eight successive hours; one with a furnace adapted with Baker's improvement, and the other with the same furnace after it had been restored to the original condition, as it had been previously in use at those works. The boiler used was a plain cylindrical one, such as does not ordinarily evaporate more than six pounds of water for one pound of coal, and no alteration was made in the setting of it, other than to insert the bridges or inverted arches, which constitute Baker's improvement. The same coal was used in the two experiments; they were conducted in the same manner, the water evaporated and the coal used, as also the residuum of clinker and ashes, being carefully weighed.

The result of the two experiments was, that after deducting the unburned coal, clinker and ashes, in order to obtain the exact effective force of the coal burned, with Baker's Furnace, 9 908-1000 pounds of water were evaporated from boiling point for every pound of coal burnt; while without Baker's improvement, 7 905-1000 pounds were evaporated. Advantage in favor of Baker's Furnace, 25 3-10 per cent.

We have also examined the notes of another detailed experiment made by Messrs. J. R. Hodges and E. N. Winslow, at the instance

of William P. Parrott, Esq., in which Baker's Furnace was compared with a furnace set by Otis Tufts. The result was that the amount of water evaporated from boiling point for each pound of fuel with Baker's Furnace was 10 707-1000 pounds; with the other furnace, 8 768-1000 pounds. Advantage in favor of Baker's Furnace, 22 per cent.

An experiment reported by Mr. A. A. Hayes, Assayer to the State of Massachusetts, undertaken at the Flour Mill at East Boston, showed that without Baker's Furnace 7 66-100 pounds of water were evaporated by one pound of coal, while with Baker's Furnace 10 9-10 pounds appeared to be evaporated, an advantage of 42 per cent. in favor of Baker's Furnace. Dr. Hayes, however, was inclined to think that the comparison would be more correct if an allowance were made by which the quantity of water evaporated with Baker's Furnace is set down at 9 6-10 pounds, showing an advantage in favor of Baker's Furnace of 25 per cent., and, as he justly observes, "placing this form of furnace among the most economical known."

Dr. Hayes adds, "This form of furnace permits the combustion of bituminous coal so perfectly that its steam-producing power comes to be estimated as high as that of anthracite, while a mixture of equal parts of anthracite and bituminous coals, gives a high evaporative effect."

Dr. Charles T. Jackson certifies that he has "entire confidence in the correctness" of experiments and observations made at the Portsmouth Steam Cotton Factory, by Mr. J. S. Kendall, his assistant, and the calculations based thereon made by Mr. Joseph Peabody, who also studied with him. These experiments showed, as the mean of two trials, that with Baker's Furnace, 8 255-1000 pounds of water were evaporated for every pound of coal burned, while with the old furnace 6 136-1000 pounds were evaporated. Advantage in favor of Baker's Furnace, 34 1-2 per cent. This is the advantage as shown by the evaporation of water. Mr. Peabody adds, "the gain in regard to power must have been greater than in that by evaporation; and more than 34 4-10 per cent. of horses' power was obtained by the new boilers (Baker's Furnace) than with the old, although from the nature of the trials it is impossible to state exactly how much more."

In noticing the results of these experiments we have only mentioned the decisive test of comparison. The results as recorded at length, in detail, comprise a great deal of interesting information, and the computations are so fully given in each case as to make the existence of

any error materially impairing the deduction in favor of the new arrangement, extremely improbable, if not impossible.

There are a number of other authentic experiments reported, less elaborately undertaken and with the results stated in less detail. But we know of no instance in which a full and fair experiment has been made which has resulted adversely to Baker's Furnace. In all the cases which have come to our notice, in which a less successful result has been reported, from the investigation which we have been able to give to the facts, we have satisfied ourselves that the unfavorable result ought not to be attributed to any defect in the principle of the Furnace, but to some accidental circumstance. Such instances are few, and they do not appear to us to be supported by such evidence as would entitle them to weigh against the positive detailed testimony above recorded.

The results of the particular experiments above described are recapitulated in the following table, showing the quantity of water evaporated for every pound of coal burned :—

	With Baker's furnace.	Without Baker's furnace.	Advantage in favor of Baker's F.
			per cent.
Lawrence Scientific School,	9.179	6.317	45.3
New England Engineers,	9.908	7.905	25.3
Messrs. Hodges & Winslow,	10.707	8.768	22.1
East Boston Flour Mill,	10.9	7.66	42.3
Ditto, with allowance,	9.6	7.66	25.3
Portsmouth Steam Cotton Factory,	8.255	6.136	34.5
Average			32.5

This average, we think, may safely be relied on. We have not included Mr. Wicksteed's experiment in the table, because it did not furnish a comparison with furnaces in common use in this country, but with an improved apparatus, so that he himself, as above quoted, confidently expresses the opinion that an average saving of 37 per cent. has been effected in American establishments.

It should be observed that all of the experiments here described were made before the addition of Mr. Amory's flue for feeding the fire with warm air, an important improvement, which produces a manifest saving of fuel, the amount of which has not been tested by any exact experiments.

The great economy of fuel which this invention allows will doubtless present its strongest claim for general introduction. It moreover allows the use of coal of all kinds, bituminous as well as anthracite, and of all qualities. And the combustion is so perfect that no black smoke, and scarcely any other escapes, which is a consideration of great importance in cities and crowded localities.

We do not undertake, however, to enter upon an argument in favor of this contrivance, but simply to present in a compact form the results of careful and recorded experiments from which others can draw, &c.

NATHAN HALE,
SAM'L A. ELIOT.
W. H. SWIFT.

BOSTON, August 17, 1855.

REPORT UPON AN IMPROVEMENT

IN

STEAM BOILER FURNACES.

BY MESSRS. RICHMOND JONES, JR., AND CHARLES S. HOMER, JR., OF THE LAWRENCE SCIENTIFIC SCHOOL, HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Having been designated by Professors Horsford and Eustis, of the Lawrence Scientific School, Harvard University; in compliance with a request made to them by J. Amory, Esq., to superintend some experiments for the purpose of testing the comparative merits of Baker's Furnace, and the old method; we now submit the following as the results of the said experiments:

These experiments were made at the Neponset Mills, Canton, Massachusetts. The boilers used were plain cylindrical, and set as in the accompanying diagram. Only three were used.

The first trial commenced on March 31st, 1853. On the 29th, the boilers had been used in connection with the engine all day. On the evening of the 30th, fires were lighted again, and experiments commenced the following morning. The pressure of steam on the boilers was raised to 15 lbs., as indicated by a steam guage, and then blown off; the same course being pursued in both experiments upon the evaporation of water.

The method of conducting the experiments was substantially as follows:—Fires were first lighted under *all* the boilers, the amount of coal, kindlings, &c., being carefully noted. After the boilers had

reached a temperature of 212°, the doors of ash-pit and furnace connected with two of them was closed up entirely and continued so during the remainder of the experiment.

The water was kept as nearly as possible at the second guage-cock, especially at the commencement and close of each experiment. A water-guage being attached to the boilers, the weight of each charge of water was carefully noted, and also its temperature, it having to pass through a cask placed upon a scale before entering the boilers. Each charge of coal was also carefully weighed before it was allowed to pass into the furnace. The time at which water was introduced into the boilers, or coal into the furnace, was noted, and also the temperature of the air in the boiler-room on those occasions, and the time the furnace doors were open.

From time to time the temperature of the external air was taken as well as that of the chimney. Unfortunately we were unable to determine the latter except in the first experiment, being unable to procure thermometors of sufficient range. At the close of each trial the waste material, including ashes, clinkers, and cinders, or half-burnt coal, was carefully weighed after it had been allowed to cool. While the steam was blowing off, care was taken to close the doors of the ash-pit, in order to prevent useless expenditure of heat.

After the close of the first experiment, Professors Horsford and Eustis suggested that others should be tried in order to ascertain the *comparative* merits of the new and old method of setting Steam Boilers. Accordingly the latter were commenced on the 12th of April; first, with Baker's Furnace in connection with the Engine. Fires were then taken out, and after the boilers were sufficiently cool, the *three* middle curves were taken out, leaving the first and the last bridges and curves. Then followed the trial in connection with the Engine, and afterwards that of the evaporation of water, the latter being conducted in so far as possible after the same method as the first. The only departure was in this; that in the latter everything had been at a high temperature for several days previous, while in the former twenty-four hours had intervened between the time of clearing grates, and the commencement of the experiment.

In the first trial with the Engine the average pressure of steam in boilers was 60 lbs.; in the last 70 lbs. It would be well to note that in the last trial with the Engine, the *three* boilers were unable to supply sufficient steam to keep up the speed, and it was found necessary to fire up the other boilers. Steam was let on from the latter twice

during the day. The first about fifteen minutes; the last twenty minutes.

The coal used was "Forest Improvement (Heckshire) Co.," (anthracite,) of very uniform size; average size in the first experiment about 0.625 lbs.; in the last 0.7 lbs. Cumberland coal (bituminous) was introduced from time to time to test the relative merits of the two Furnaces as smoke burners. Much less smoke passed off with the Furnace than without. Allowance was made for kindlings as being equivalent to half their weight in coal.

Annexed will be found the "Details" of all the experiments, and also a "Tabular View" of each.

In the trials with the Engine, in both cases, the Engine was stopped for half an hour in the morning, and three-quarters of an hour at noon. Without the Furnace the fires were not so bright as with, the difference in this respect being very marked.

Signed, RICHMOND JONES, Jr.,
C. S. HOMER, Jr.,
Lawrence Scientific School,

CAMBRIDGE, *May 2d,* 1853.

EXPERIMENT WITH BAKER'S FURNACE.

Details.

Commencing Thursday, A. M., March 31, 1853.	Time.	Temp. of Air.	Temp. of Water.	Water added.	Coal added	Furnace doors open	Kindlings.	Remarks.
	h. m.	°	°	*lbs.*	*lbs.*	*m. s.*	*lbs*	
Evaporation of water	a. m.							
	3.35	64			338		48	
	4.15	64	48	63				
	5.00	64	48	223				
	5.50					.20		
	6.05	67	47	119				
	6.40							Temp. of chimney 140°.
	7.05	69	47	240				
	7.10	69			149	2.00		
	7.30					.40		
	7.45	68				.35		
	8.00					1.45	37	
	8.30				53	.40		
	8.40	66			90	2.40		
	10.00		46	320				Chimney 222°.
	10.45	66	48	315	90	1.35		
	11.35	69	47	505				
	12m.					.50		
	p. m.							
	12.25	69	46	310	90	1.30		
	12.45							Chimney 220°.
	1.00					2.00	9	External air 68°.
	1.25					1.00	18	
	1.35				90	6.30	9	Clearing grate.
	2.15	69	46	300		1.00		
	2.35				90	2.20		
	3.00					1.05		
	3.30	68	46	400				
	3.45				22	2.05		Coal here added
	4.15	70	48	500	90	3.45		was "Cumberland."
	4.55		48	500				
	4.15	62	47	500		1.40		Chimney 170°.
	5.30				90	1.30		
	6.30	64	48	563		1.00		
	7.25		48	619	90	4.00		
	8.20	62	48	600				
	9.15	61	49	619		1.00		
	10.00	60	49	600	90	4.00		
	10.55	60	48	600				
	11.35	60	48	600				

Commencing Friday, A. M., April 1, 1853.	Time.	Temp. of Air.	Temp. of Water.	Water added.	Coal added	Furnace doors open.	Kindlings.	Remarks.
	h. m	°	°	*lbs.*	*lbs.*	*m. s.*	*lbs*	
	a. m.							
	12.20	59	48	600				
	12.55				90	3.45		
	1.30	59	48	600				Chimney 136°.
	2.10	60	48	600		2.40		
	3.00	68	48	600				
	4.00	70	48	600				
	4.25				90	7.40		Cleaning grate.
	5.30	70	48	600				
	6.15							Chimney 187°.
	6.50	71	48	600	90	3.00		
	7.15					.40		
	9.00	67	48	600				
	9.55	68	48	500	90	3.30		Ashes taken out
	10.45		47	500				161.
	11.25				90	2.20		Chimney 146°.
	11.40					1.25		"Cumberland
	12m.				18	....		coal," chimney
	12.20	69	50	600	90	2.30		172°.
	2.20	70			90	2.10		
	2.55	66	52	600				Chimney 156°.
	3.20					3.00		Ex. air 43°.
	4.10	70	51	600				
	5.05	70	46	600		1.20		
	5.30					.15		
	6.00	72	48	600		3.40		
	7.00	70		600				
	7.15				90	2.40		
	8.00	68	50	600				
	9.15	65	52	300	90	1.45		
	9.45							Chimney 160°.
	10.10	68	46	600	15			
	11.35		46	505		4.35		
	11.50					2.50	43	
April 2d,	a. m.							
a. m.,	12.10				90	.20		
Saturday.	12.20					2.05		
	12.30					1.55		
	12.45					3.00		
	12.55					1.40		
	1.10	72	44	300	90	1.30		
	1.55		46	600		2.00		
	2.30	68	46	600				
	3.00	68	47	600				
	3.30	68	46	600		1.00		Ex air. 26°.
	4.00	......	......	.....	....	....	..	Exper. closed.
	48.25	66°.58	47°.68	22601	2380			Reduced to coal.

Experiment with Engine in connection with Baker's Furnace.

Commencing Tuesday, A. M. April 12, 1853.	Time.	Coal added.	Temp. of Air.	Temp. Ex. Air.	Remarks.
Time when coal was weighed out and *not* when put into furnace.	*h. m.*	*lbs.*			Damper and doors nearly closed most of the time.
	a. m.				
	4 50	180	66°		
	7 00	90		50°	
	8 00	90			
	8 40	150			
	10 00	150			
	m.				
	12 00	150			
	1 15	150			
	1 30	20 Cumberland Coal.			
	2 30	150			
	3 05	150			
	5 00 p. m.	1280	69°	49°	
Coal weighed but not consumed 122					

Experiment closed at 5 p. m., having continued 12 hours.

Experiment with Engine and without Baker's Furnace.

Commencing Thursday, A. M., April 14, 1853.	Time.	Coal added.	Temp. of Air.	Temp. Ex. Air.	Remarks.
Time when coal was weighed out, and *not* when put into furnace.	*h. m.*	*lbs.*			Doors nearly closed, but dampers open from 2 to 3 inches.
	5 30	150			
	5 40	75	62°	44°	
	6 00	150			
	6 10	150			
	6 15	150			
	6 20	150			
	9 00	140			
	9 15	300			
	11 00	300	80°	44°	
	3 00 p. m.	600			
	5 00		80°	38°	
	5 30	150			
		2315			
	6 45	Experiment closed, hav- continued $13\frac{1}{4}$ hours.			

NOTE.—At 5.45 a. m. pressure of steam got so low that we were obliged to stop the engine till 7 a. m.; when we again started with *five* boilers, shutting off the steam from two of them in a few moments. At 8.30 a. m. we were again obliged to let on steam from the other two boilers to prevent diminution of speed.

Commencing Thursday, April 14, 1853.	Time.	Temp. of Air,	Temp. of Water.	Water added.	Coal added	Funace doors open.	Kindlings.	Remarks.
	h. m.	°	°	*lbs.*	*lbs.*	*m. s.*	*lbs.*	
	p. m.						150	Cinders, or half burnt coal.
	7.30				300			
	7.40	89			150	.30		
	8.25	84				.45		
	8.30	83	52	600				
	9.10	82	52	540	150	1.30		
	9.45		52	500				
	10.45		50	500				
	m. 12	77	50	500	150	1.10		
Friday,	a. m.							
a.m. April	1.15	73	49	500				
1853.	2.15	75	48	500				
	2.50				150	2.		
	3.20	72	50	500				
	3.55				150	1.40		
Evaporation of water.	4.20	68	49	500				
	5.	69	50	500				
	6.	68	50	620				Ex. air 31°.
	6.55	70	49	500				
	8.10	70	48	535	150	4.45		
	8.35				150	1.35		
	8.50	69	47	500				
	9.30	70	48	500		1.		
	10.15	69	48	500				
	10.35					1.25		
	10.50	70	48	500				
	11.25	70	48	500				
	12 m.	72	48	500	150	3.25		
	12.15				150	1.45		
	1.05	70	49	515				
	1.35	72	49	500		1.05		
	2.20		50	500				Ex. air 51°.
	3.00				150	1.25		
	3.20	71	50	500				
	4.00	70	50	500	102	1.35		
	5.25	67	50	500				
	5.40				150	1.45		
	6.30	71	50	500				
	7.40		50	500				
	8.10				150	1.		
	8.50				150	4.50		
	10.20	69	50	500	150	1.30		
	11.55	68	50	500	150	1.20		

Commencing Saturday, A. M., April 16, 1853.	Time.	Temp. of Air.	Temp. of Water.	Water added.	Coal added	Furnace doors open.	Kindlings.	Remarks.
	h. m.	°	°	lbs.	lbs.	m. s.	lbs.	
	a. m.							
	1.05	67	50	500				
	2.15		50	500				
	2.40				150	2.		
	3.25	67	50	500				
	4.25		50	500				
	5.20	66			150	1.40		Ex. air 54°.
	5.45	65	50	620		3.30		
	6.50	69	51	500				
	7.00	69	48	500				
	8.45	67	48	500	150	3.00		
	9.25					2.55		
	10.25	69	49	500	150	1.20		
	11.25	68	48	500				
	p. m.							
	12.30	67	49	500		2.55		
	1.20	71	50	600	150	.05		
	2.00							Ex. air 55°.
	2.45	72	50	500				
	3.20	74	50	500	150	1.45		
	4.15	73	51	500				
	4.30				19	.35		Cumberland coal here added
	6.00	73	50	500				Ex. air 42°.
	7.30	Experi	ment cl	osed h	avi'g	con	tinue	d 48 hours.
	48.00	71.07	49.51	23030	3571		75	Reduc'd to coal

EVAPORATION OF WATER.

Experiment with Baker's Furnace.—Commencing Thursday, March 31*st*, 1853—*Nesponset Mills, Canton, Mass.—*
Tabular View.

Water evaporated— - - - -	22601 lbs.
Coal passed into Furnace— - - -	2462
Clinkers, 111 lbs.—Ashes 302 do—cinders, or coal remaining in Furnace, 448 do—Total weight of waste material—	861
Pure carbon consumed— - - - -	1601
Water evaporated to a pound of Coal— - -	9.179
Water evaporated to a pound of carbon— - -	14.116
" " " of coal from 212° (latent heat 1000°)	10.684
" " " carbon from 212° "	16.431
Coal used per hour— - - - -	50.85
Coal used per hour per sq. ft. of grate surface— -	2.38
Coal used per sq. ft. of effective boiler surface per hour—	0.1695
Kindlings reduced to coal— - - -	82
Mean temperature of air— - - -	66°.58
Mean temperature of water— - - -	47°.68
Duration of experiment— - - -	48h. 25m.

Experiment without Baker's Furnace.—Commencing Thursday, April 14*th*, 1853.

Water evaporated— - - - - - -	33030 lbs.
Coal passed into furnace— - - - - -	3646
Clinkers, 158.—Ashes, 168.—Cinders, 320 lbs.	
Total weight of waste material— - - - -	646
Pure carbon consumed— - - - - -	3000

Tabular View.

Water evaporated to a pound of coal— - - -	6.317 lbs.
Water evaporated per pound of carbon— - - -	7.676
" " " of coal from 212° (latent heat 1000°)	7.340
" " " of carbon from 212°— - -	8.619
Coal used per hour— - - - - - -	75·958
Coal used per sq. ft. of grate surface per hour— - -	309
Coal used per sq. ft. of effective boiler surface per hour—	0.253

Kindlings reduced to coal— - - - - -	75
Mean temperature of air— - - - - -	71°.07
Mean temperature of water— - - - -	49°.51
Duration of experiment— - - - - -	48 hours.

Trial with Baker's Furnace in connection with the Engine.—
Commencing Tuesday A. M., April 12*th*, 1853.

Total weight of coal consumed— - - - -	1158 lbs.
Clinkers, 174 lbs. Ashes, 134 lbs.—waste material—	304
Coal consumed per hour— - - - - -	96.5
Coal consumed per hour per Horse Power— - -	2.193
Duration of experiment— - - - - -	12 hours.

Engine doing work equivalent to 44 Horse power.

Trial without Baker's Furnace in connection with the Engine
Commencing Thursday A. M., April 14*th*, 1853.

Total weight of coal consumed— - - - -	2315 lbs.
Clinkers, 192 lbs. Ashes, 65 lbs. Cinders, including 150 lbs. left in Furnace to rekindle fires for next experiment,—	338
Total waste material— - - - - - - -	595

Tabular View.

Coal consumed per hour - - - - - -	174.716 lbs.
Coal consumed per Horse Power per hour - - -	3.97
Duration of experiment - - - - -	13h. 25m.

Engine doing work equal to 44 Horse Power, 13¼ hours.

Data in reference to Boilers, Furnace and Engine. Boilers, five in number, were set as in the accompanying Diagram; of these *three* only were used. Length 30 ft. Diameter 2 ft. Arc of boiler surface exposed to action of fire 3'.4 in.

Area of boiler surface exposed to action of fire -	300 sq. ft.
Area of ash pit doors 1.979 ft. each. All three -	5.937 sq. ft.
Area of surface doors 1.277 sq. ft. each, All three	3.831 sq. ft.
Area of grate surface, (bars 3 ft in length - -	21.326
Cubical contents of ash pit - - - - -	34.172 cu. ft.

Engine used in connection with boilers, of Corliss & Nightingale's manufacture. Nominal power equivalent to 50 Horse Power. Variable "cut off."

Diameter of cylinder - - - - - -	14 inches.
Length of stroke - - - - - -	4 ft.

Regular speed 44 revolutions per minute.

During experiments attached to 232 Looms.

One of us being on the spot both day and night, we believe there can be no possibility of error in our Notes from which the above results were taken.

RICHMOND JONES, Jr.
C. S. HOMER, Jr.

Messrs. Jones and Homer have been designated from the Departments of Engineering and Chemistry in the Scientific School of Harvard University, to make the experiments above detailed.

Their record bears intrinsic evidence of the care and fidelity with which the experiments have been conducted; and although a result so surprising will be received with caution, still with considerable allowance for possible error, it may be safely said, that it shows the decided superiority of Baker's Furnace as applied to long plain cylindrical boilers over any with which experiments have been made and recorded, where the end to be gained was the evaporation of the largest quantity of water with a given weight of fuel.

Signed E. N. HORSFORD,
Rumford Professor, Harvard University.

Cambridge, May 2d, 1853.